(12) UK Patent Application (19) GB (11) 2 194 086 (13) A

(43) Application published 24 Feb 1988

(21) Application No 8717088

(22) Date of filing 20 Jul 1987

(30) Priority data
(31) 61/173645 (32) 25 Jul 1986 (33) JP

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(51) INT CL⁴
G06F 15/21

(52) Domestic classification (Edition J):
G4A UB

(56) Documents cited
GB 1452865 US 4183083 US 3648253
GB 1339090 US 3662401 US 3643227

(58) Field of search
G4A
Selected US specifications from IPC sub-class G06F

(54) Job scheduling

(57) A job scheduling method for scheduling of job allocation to various resources (people or equipment), wherein a workload is allocated (103, 106) to each time unit along a time axis in units of job and resource type. Based on the workload allocated in units of resource type, an initial workload for all resources at each time unit is calculated (113). A first workload balancing (104, 107) is performed at a time unit where an initial workload exceeds a resource capacity so as to balance the initial workload within the resource capacity. Thereafter, a second workload balancing (104, 108) is performed so as to balance a workload allocated in units of resource type within its resource capacity, and the schedule is output (105).

FIG. 1

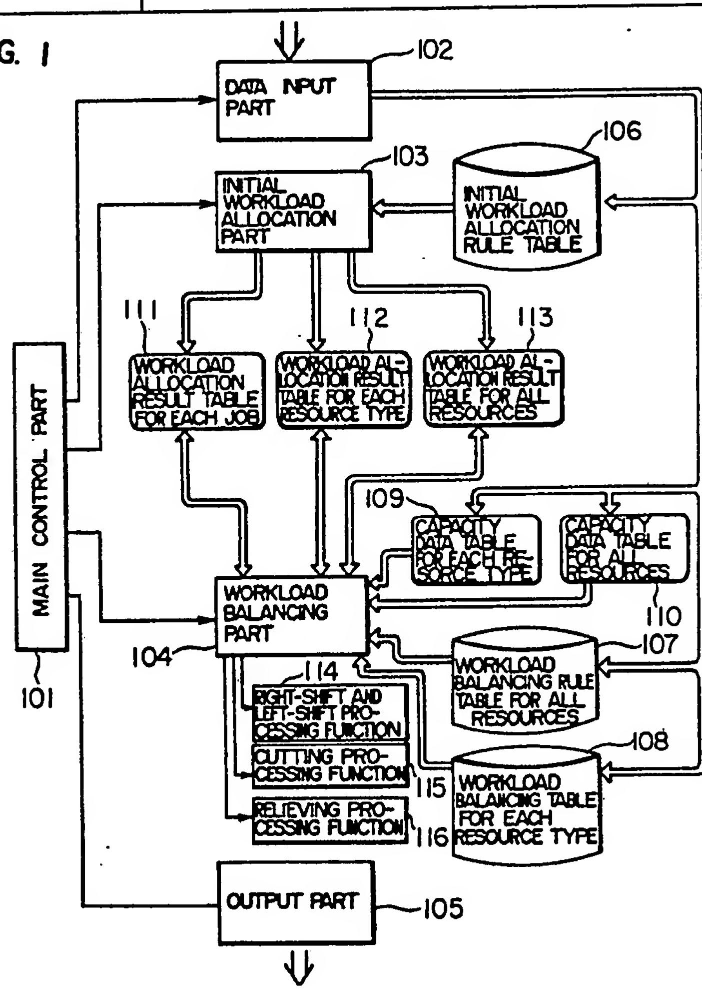

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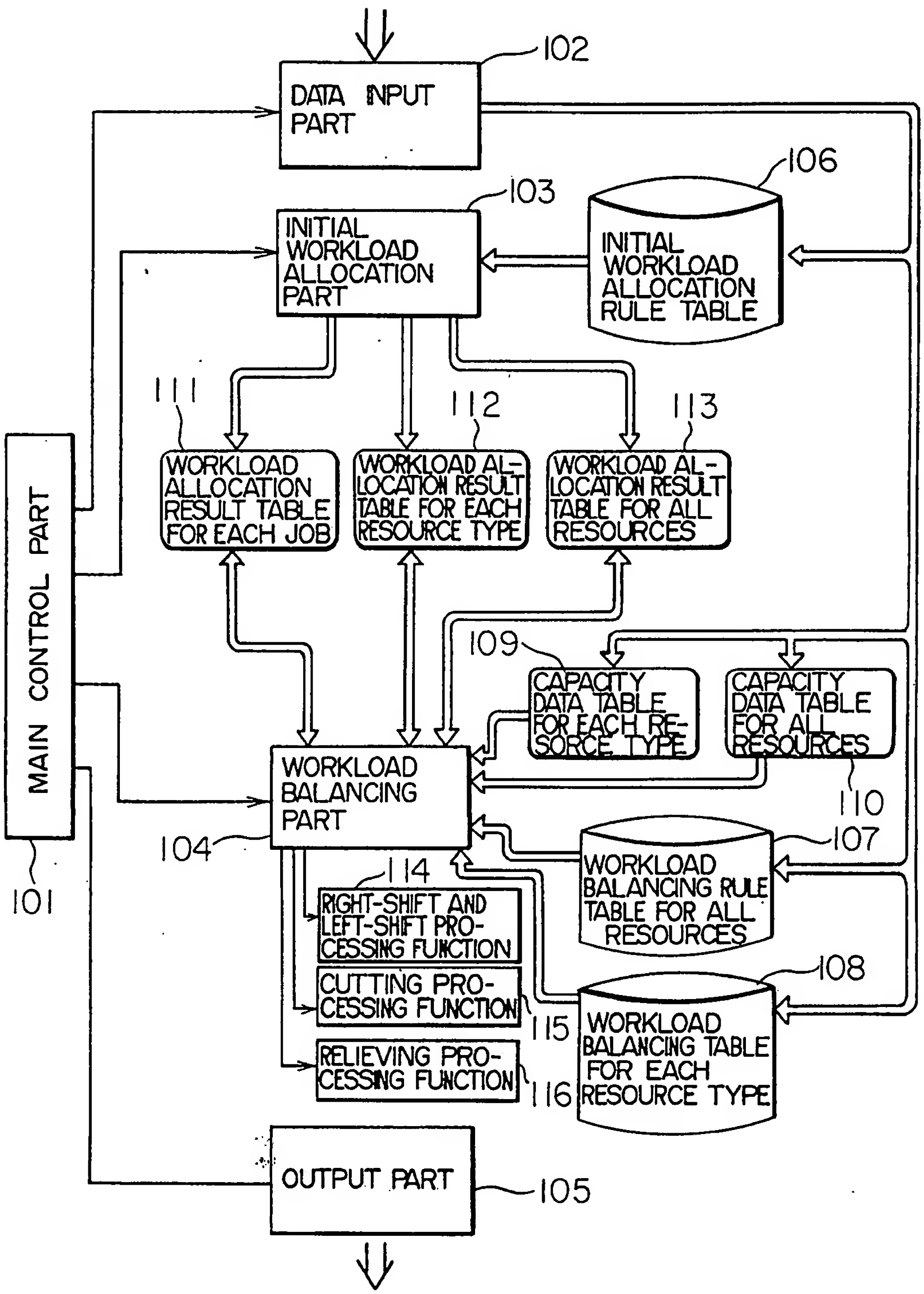
FIG. 1



DATA INPUT PART
102
INITIAL WORKLOAD ALLOCATION PART
103
INITIAL WORKLOAD ALLOCATION RULE TABLE
106
MAIN CONTROL PART
101
WORKLOAD ALLOCATION RESULT TABLE FOR EACH JOB
111
WORKLOAD ALLOCATION RESULT TABLE FOR EACH RESOURCE TYPE
112
WORKLOAD ALLOCATION RESULT TABLE FOR ALL RESOURCES
113
CAPACITY DATA TABLE FOR EACH RESOURCE TYPE
109
CAPACITY DATA TABLE FOR ALL RESOURCES
110
WORKLOAD BALANCING PART
104
WORKLOAD BALANCING RULE TABLE FOR ALL RESOURCES
107
RIGHT-SHIFT AND LEFT-SHIFT PROCESSING FUNCTION
114
CUTTING PROCESSING FUNCTION
115
RELIEVING PROCESSING FUNCTION
116
WORKLOAD BALANCING TABLE FOR EACH RESOURCE TYPE
108
OUTPUT PART
105

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FIG. 2

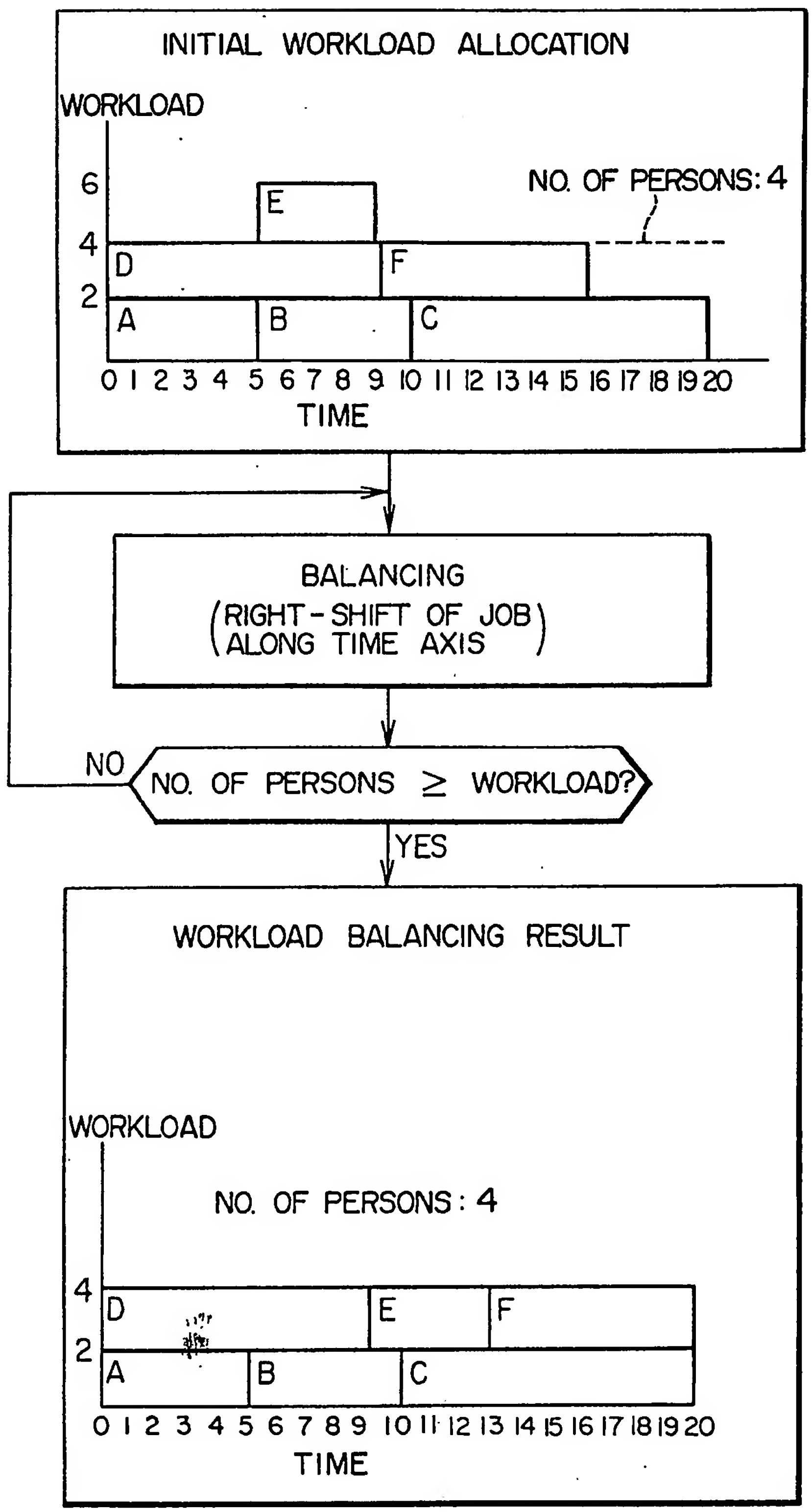


FIG. 3

INITIAL WORKLOAD ALLOCATION RULE TABLE 106

JOB NO. P'_1	RESOURCE TYPE NO. P'_2	NUMBER OF PERSONS P_3	START TIME UNIT NO. P'_4	FINISH TIME UNIT NO. P'_5

FIG. 4

WORKLOAD BALANCING ROLE TABLE 107

JOB NO. P'_1	EARLIEST START TIME NO. P'_2	LATEST START TIME NO. P'_3	WORKLOAD BALANCING MEANS (RIGHT-OR LEFT-SHIFT OR CUT) P_4	PRIORITY ORDER P_5	CONTROL FLAG ·APPLICABLE; 0 ·NOT APPLICABLE; 1

FIG. 5

WORKLOAD BALANCING RULE TABLE FOR EACH RESOURCE TYPE 108

RESOURCE TYPE NO. OF EXCESSIVE WORKLOAD P'_1	JOB NO. P'_2	RELIEVED RESOURCE TYPE NO. P'_3	PRIORITY ORDER P_4	CONTROL FLAG APPLICABLE; 0 NOT APPLICABLE; 1

FIG. 6

CAPACITY DATA TABLE FOR EACH RESOURCE 109

TIME UNIT NO. (j) / RESOURCE TYPE NO. (i)	1	2	3	---	j	---	J
1							
2							
⋮							
i					$\ell(i,j)$		
⋮							
I							

FIG. 7

CAPACITIVE DATA TABLE FOR ALL RESOURCES 110

TIME UNIT NO. (j)	1	2	3	---	j	---	J
RESOURCE CAPACITY($\ell(j)$)							

FIG. 8

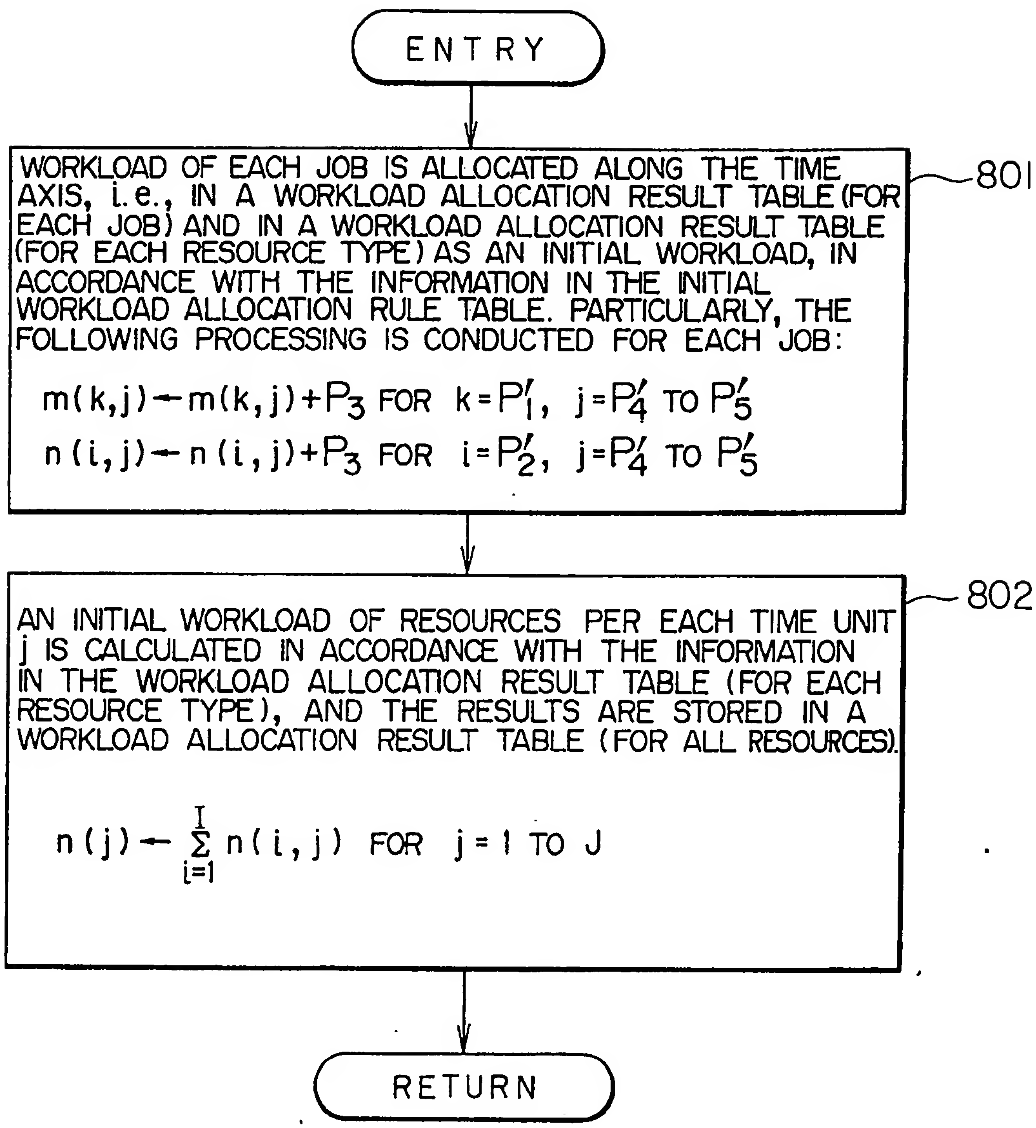

ENTRY
WORKLOAD OF EACH JOB IS ALLOCATED ALONG THE TIME AXIS, i.e., IN A WORKLOAD ALLOCATION RESULT TABLE (FOR EACH JOB) AND IN A WORKLOAD ALLOCATION RESULT TABLE (FOR EACH RESOURCE TYPE) AS AN INITIAL WORKLOAD, IN ACCORDANCE WITH THE INFORMATION IN THE INITIAL WORKLOAD ALLOCATION RULE TABLE. PARTICULARLY, THE FOLLOWING PROCESSING IS CONDUCTED FOR EACH JOB:
$m(k,j) \leftarrow m(k,j)+P_3$ FOR $k=P_1'$, $j=P_4'$ TO P_5'
$n(i,j) \leftarrow n(i,j)+P_3$ FOR $i=P_2'$, $j=P_4'$ TO P_5'
801
AN INITIAL WORKLOAD OF RESOURCES PER EACH TIME UNIT j IS CALCULATED IN ACCORDANCE WITH THE INFORMATION IN THE WORKLOAD ALLOCATION RESULT TABLE (FOR EACH RESOURCE TYPE), AND THE RESULTS ARE STORED IN A WORKLOAD ALLOCATION RESULT TABLE (FOR ALL RESOURCES).
$n(j) \leftarrow \sum_{i=1}^{I} n(i,j)$ FOR $j=1$ TO J
802
RETURN

FIG. 9

WORKLOAD ALLOCATION RESULT TABLE FOR EACH JOB 111

TIME UNIT NO. (j) / JOB NO. (k)	1	2	3	---	j	---	J
1							
2							
⋮							
k					m (k, j)		
⋮							
K							

FIG. 10

WORKLOAD ALLOCATION RESULT TABLE FOR EACH RESOURCE TYPE 112

TIME UNIT NO. (j) / RESOURCE TYPE NO. (i)	1	2	3	---	j	---	J
1							
2							
⋮							
i					n (i, j)		
⋮							
I							

FIG. 11

WORKLOAD ALLOCATION RESULT TABLE FOR ALL RESOURCES 113

TIME UNIT NO. (j)	1	2	3	---	j	---	J
RESOURCE CAPACITY(n(j))							

FIG. 12

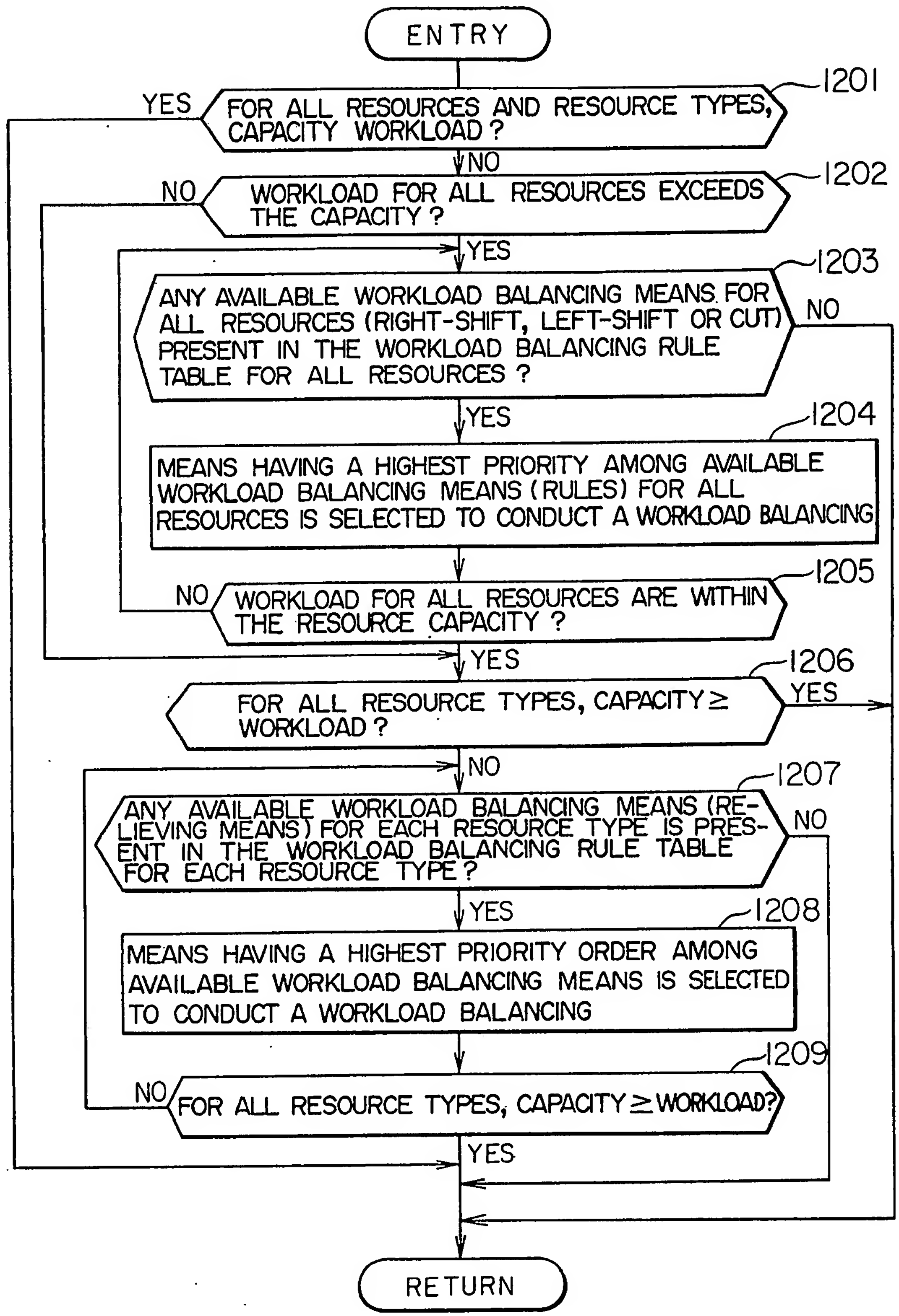

ENTRY
1201
YES
FOR ALL RESOURCES AND RESOURCE TYPES, CAPACITY WORKLOAD ?
NO
1202
NO
WORKLOAD FOR ALL RESOURCES EXCEEDS THE CAPACITY ?
YES
1203
ANY AVAILABLE WORKLOAD BALANCING MEANS FOR ALL RESOURCES (RIGHT-SHIFT, LEFT-SHIFT OR CUT) PRESENT IN THE WORKLOAD BALANCING RULE TABLE FOR ALL RESOURCES ?
NO
YES
1204
MEANS HAVING A HIGHEST PRIORITY AMONG AVAILABLE WORKLOAD BALANCING MEANS (RULES) FOR ALL RESOURCES IS SELECTED TO CONDUCT A WORKLOAD BALANCING
1205
NO
WORKLOAD FOR ALL RESOURCES ARE WITHIN THE RESOURCE CAPACITY ?
YES
1206
FOR ALL RESOURCE TYPES, CAPACITY ≥ WORKLOAD ?
YES
NO
1207
ANY AVAILABLE WORKLOAD BALANCING MEANS (RELIEVING MEANS) FOR EACH RESOURCE TYPE IS PRESENT IN THE WORKLOAD BALANCING RULE TABLE FOR EACH RESOURCE TYPE ?
NO
YES
1208
MEANS HAVING A HIGHEST PRIORITY ORDER AMONG AVAILABLE WORKLOAD BALANCING MEANS IS SELECTED TO CONDUCT A WORKLOAD BALANCING
1209
NO
FOR ALL RESOURCE TYPES, CAPACITY ≥ WORKLOAD?
YES
RETURN

FIG. 13

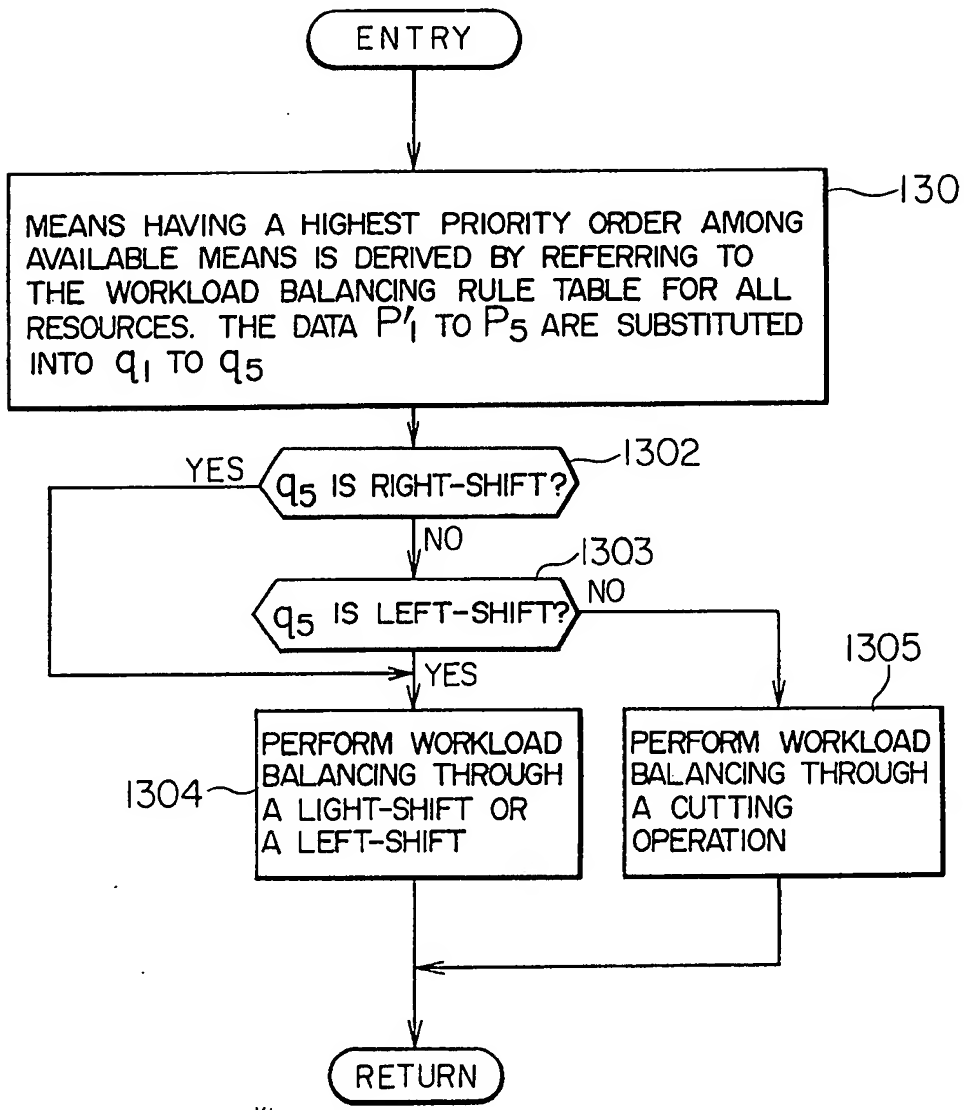

ENTRY
MEANS HAVING A HIGHEST PRIORITY ORDER AMONG AVAILABLE MEANS IS DERIVED BY REFERRING TO THE WORKLOAD BALANCING RULE TABLE FOR ALL RESOURCES. THE DATA P'1 TO P5 ARE SUBSTITUTED INTO q1 TO q5
1301
q5 IS RIGHT-SHIFT?
1302
YES
NO
q5 IS LEFT-SHIFT?
1303
NO
YES
PERFORM WORKLOAD BALANCING THROUGH A LIGHT-SHIFT OR A LEFT-SHIFT
1304
PERFORM WORKLOAD BALANCING THROUGH A CUTTING OPERATION
1305
RETURN

FIG. 14

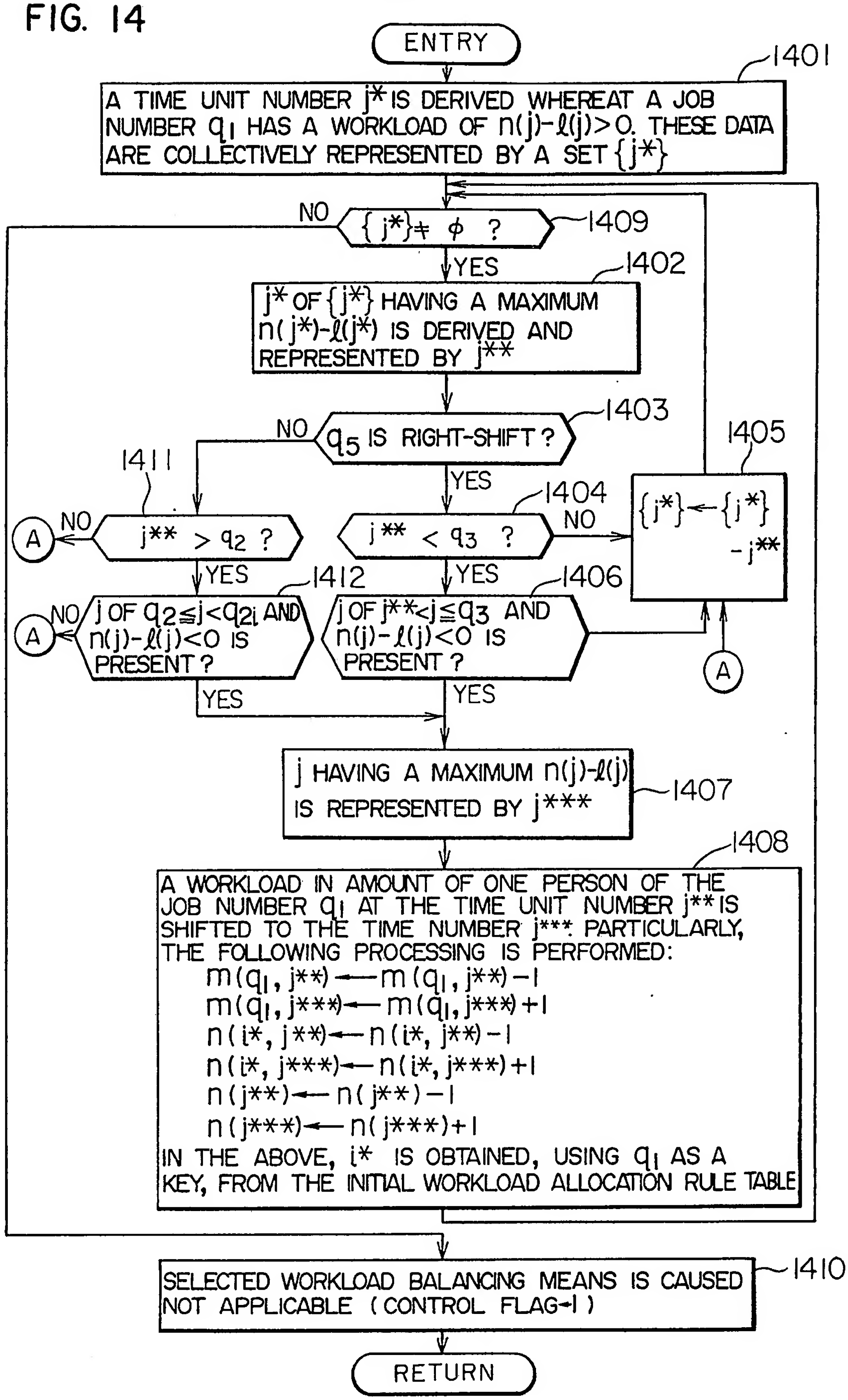

ENTRY
1401
A TIME UNIT NUMBER j* IS DERIVED WHEREAT A JOB NUMBER q1 HAS A WORKLOAD OF n(j)-ℓ(j)>0. THESE DATA ARE COLLECTIVELY REPRESENTED BY A SET {j*}
1409
{j*}≠φ ?
NO
YES
1402
j* OF {j*} HAVING A MAXIMUM n(j*)-ℓ(j*) IS DERIVED AND REPRESENTED BY j**
1403
q5 IS RIGHT-SHIFT ?
NO
YES
1411
j** > q2 ?
NO
A
YES
1404
j** < q3 ?
NO
YES
1405
{j*}←{j*} - j**
1412
j OF q2≦j<q2i AND n(j)-ℓ(j)<0 IS PRESENT ?
NO
A
YES
1406
j OF j**<j≦q3 AND n(j)-ℓ(j)<0 IS PRESENT ?
YES
A
1407
j HAVING A MAXIMUM n(j)-ℓ(j) IS REPRESENTED BY j***
1408
A WORKLOAD IN AMOUNT OF ONE PERSON OF THE JOB NUMBER q1 AT THE TIME UNIT NUMBER j** IS SHIFTED TO THE TIME NUMBER j***. PARTICULARLY, THE FOLLOWING PROCESSING IS PERFORMED:
m(q1, j**) ← m(q1, j**) - 1
m(q1, j***) ← m(q1, j***) + 1
n(i*, j**) ← n(i*, j**) - 1
n(i*, j***) ← n(i*, j***) + 1
n(j**) ← n(j**) - 1
n(j***) ← n(j***) + 1
IN THE ABOVE, i* IS OBTAINED, USING q1 AS A KEY, FROM THE INITIAL WORKLOAD ALLOCATION RULE TABLE
1410
SELECTED WORKLOAD BALANCING MEANS IS CAUSED NOT APPLICABLE (CONTROL FLAG←1)
RETURN

FIG. 15

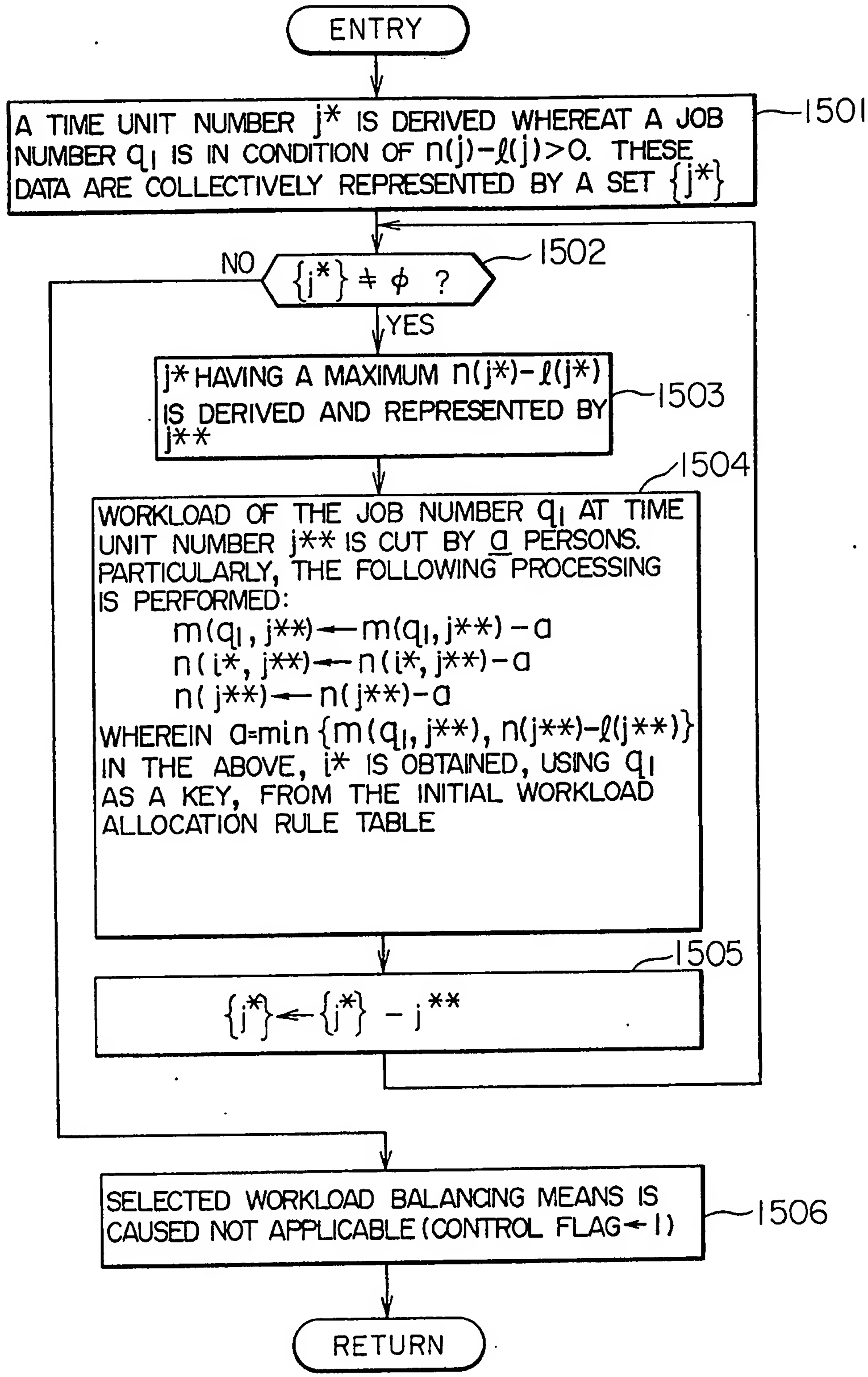
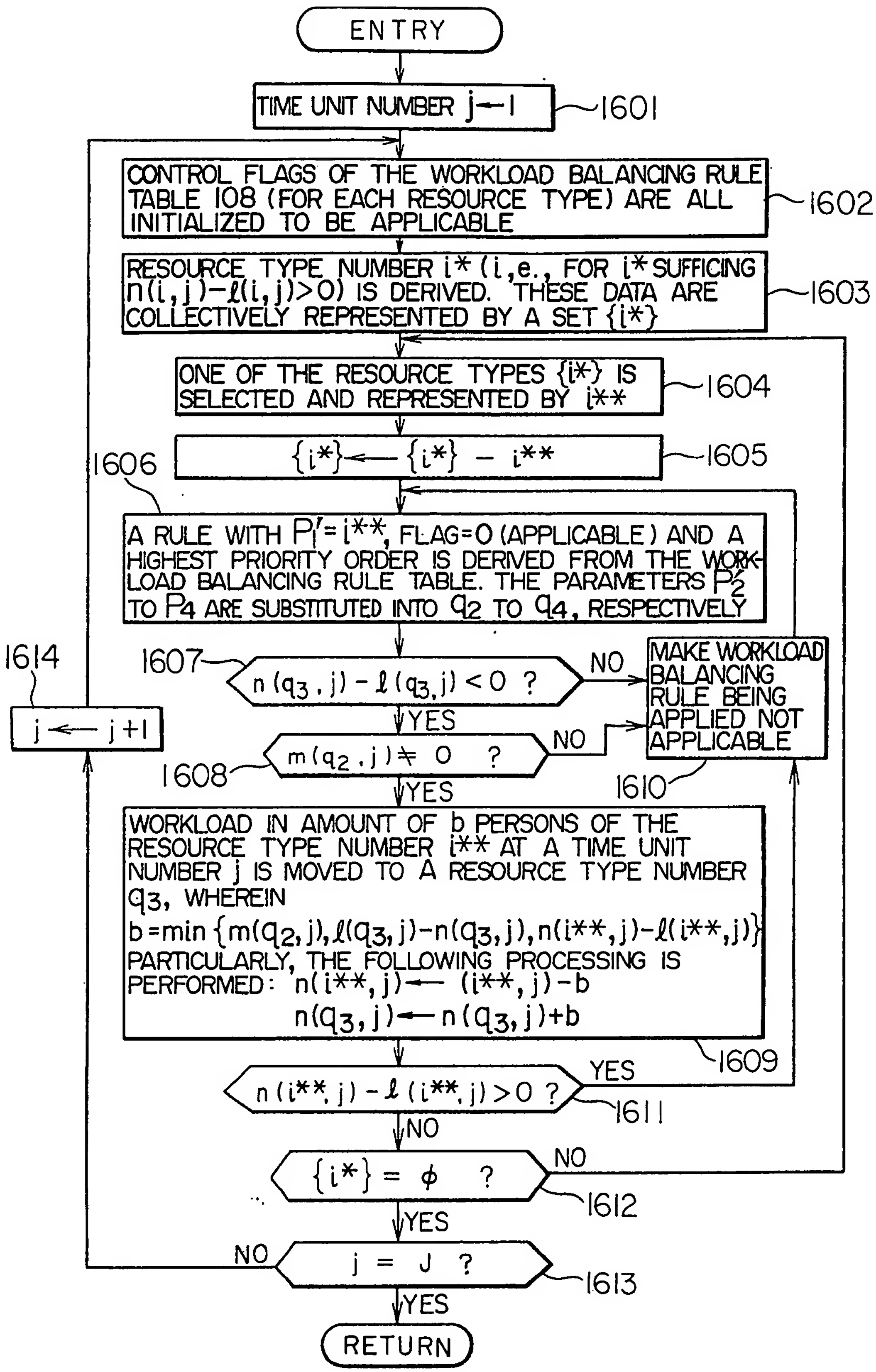

ENTRY
A TIME UNIT NUMBER j^* IS DERIVED WHEREAT A JOB NUMBER q_l IS IN CONDITION OF $n(j)-\ell(j)>0$. THESE DATA ARE COLLECTIVELY REPRESENTED BY A SET $\{j^*\}$
1501
NO
$\{j^*\} \neq \phi$?
1502
YES
j^* HAVING A MAXIMUM $n(j^*)-\ell(j^*)$ IS DERIVED AND REPRESENTED BY j^{**}
1503
1504
WORKLOAD OF THE JOB NUMBER q_l AT TIME UNIT NUMBER j^{**} IS CUT BY $\underline{a}$ PERSONS. PARTICULARLY, THE FOLLOWING PROCESSING IS PERFORMED:
$m(q_l, j^{**}) \leftarrow m(q_l, j^{**}) - a$
$n(i^*, j^{**}) \leftarrow n(i^*, j^{**}) - a$
$n(j^{**}) \leftarrow n(j^{**}) - a$
WHEREIN $a = \min\{m(q_l, j^{**}), n(j^{**})-\ell(j^{**})\}$
IN THE ABOVE, i^* IS OBTAINED, USING q_l AS A KEY, FROM THE INITIAL WORKLOAD ALLOCATION RULE TABLE
1505
$\{j^*\} \leftarrow \{j^*\} - j^{**}$
SELECTED WORKLOAD BALANCING MEANS IS CAUSED NOT APPLICABLE (CONTROL FLAG $\leftarrow$ 1)
1506
RETURN

FIG. 16



ENTRY
TIME UNIT NUMBER j←1
1601
CONTROL FLAGS OF THE WORKLOAD BALANCING RULE TABLE 108 (FOR EACH RESOURCE TYPE) ARE ALL INITIALIZED TO BE APPLICABLE
1602
RESOURCE TYPE NUMBER i* (i.e., FOR i* SUFFICING n(i,j)−ℓ(i,j)>0) IS DERIVED. THESE DATA ARE COLLECTIVELY REPRESENTED BY A SET {i*}
1603
ONE OF THE RESOURCE TYPES {i*} IS SELECTED AND REPRESENTED BY i**
1604
{i*}←{i*} − i**
1605
1606
A RULE WITH P1'=i**, FLAG=0 (APPLICABLE) AND A HIGHEST PRIORITY ORDER IS DERIVED FROM THE WORKLOAD BALANCING RULE TABLE. THE PARAMETERS P2' TO P4 ARE SUBSTITUTED INTO q2 TO q4, RESPECTIVELY
1614
1607
n(q3, j) − ℓ(q3, j) < 0 ?
NO
MAKE WORKLOAD BALANCING RULE BEING APPLIED NOT APPLICABLE
YES
j ← j+1
m(q2, j) ≠ 0 ?
NO
1608
YES
1610
WORKLOAD IN AMOUNT OF b PERSONS OF THE RESOURCE TYPE NUMBER i** AT A TIME UNIT NUMBER j IS MOVED TO A RESOURCE TYPE NUMBER q3, WHEREIN
b=min{m(q2,j),ℓ(q3,j)−n(q3,j),n(i**,j)−ℓ(i**,j)}
PARTICULARLY, THE FOLLOWING PROCESSING IS PERFORMED: n(i**,j)← (i**,j)−b
n(q3,j)←n(q3,j)+b
1609
YES
n(i**, j) − ℓ(i**, j) > 0 ?
1611
NO
NO
{i*} = φ ?
1612
YES
NO
j = J ?
1613
YES
RETURN

SPECIFICATION

Job scheduling method and system

BACKGROUND OF THE INVENTION

The present invention relates to a scheduling method for allocating a time and a job to each resource (person, installation), and more particularly to a job scheduling method suitable for a project which needs to consider a number of restrictions of the job allocation.

In order to complete a given project with limited resources (persons and installations), it is important to develop a schedule capable of allocating a suitable time and a suitable job to each resouece. Without a proper schedule, jobs may concentrate on a particular resource or no job may be allocated to another particular resource thus leading to an inability to complete a workload per day.

Job scheduling has applications to various fields. One practical scheduling method is known described, for example, in "ACTIVITY NETWORK", by Elmagraphy, pp. 144 to 149, JOHN WILEY & SONS, March 1977. A brief description of a conventional system of this type will be given with reference to Fig. 2.

First, an earliest start time is allocated to each job (indicated by A to E in the Figure) to obtain an initial workload allocation result. In the example shown in Fig. 2, it is assumed that two persons are necessary for each job and the total numbers of persons is four. According to the initial workload allocation result, six persons are required at a peak workload, which means a shortage of two persons. With a conventional system, workload balancing has been carried out to balance the workload within a limited number of persons. Since a start time for each job is given an earliest start time at the initial workload allocation, there is a job or jobs which can be shifted to the right along the time aixs, i.e., can be delayed. Therefore, a job (illustratively job F) which can be completed at the latest finish time is selected among the jobs and shifted to the right to the latest start time before the appointed time (time 20 in this example). Succeedingly, the similar procedure as above is repeated until the workload is balanced within the resource capacity.

The above conventional system, however, cannot be applied to various fields and is not suitable for the application to other than the manufacturing industry.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a job scheduling method having a wide range of applications, an excellent optimum status, a good processing efficiency and a high descriptive nature.

To achieve the above object, scheduling in various fields has been analyzed to definitely show problems arising if the above conventional system is applied to the fields other than the manufacturing industry. The problems have been solved in the manner as described in the following, taking a job scheduling in a super market as an example.

(1) An alternative resource can be used for each job. According to the present invention, although a register clerk for example should generally be a clerk, a part timer or temporary employee does the work if the register clerk is busy at another work. If not possible, a management person is impelled to do the work. According to the conventional system, each resource doing a job is defined only in a general sense.

(2) A latest start time can be given to a particular job. According to the present invention, a finish time of an order for example can be given a time as late the order due time as possible. According to the conventional system, all jobs are given earliest start times at the initial workload allocation. A finish time may be given an order due time, but it is a mere chance.

(3) As means for balancing a peak workload in excess of the resource capacity, not only start time delaying function but also start time hastening function, job cutting function and job relieving function are added. It is necessary for the order job described in the above (2) to be shifted to the left if a start time is given a latest start time at the workload allocation. Further, if there is a peak workload in excess of the resource capacity even after the shift of a start time, a job cutting of "a certain work is not done today" is effected in an actual job scheduling. Furthermore, even if the total workload does not exceed the capacity for all resources, a peak workload of a certain resource type may exceed its capacity if a resource type most suitable for each job at a time is allocated as described in the above (1). In this case, a job relieving function for relieving the job by another resource is effected to balance the peak workload.

(4) A priority order of jobs is considered in balancing the workload. There occurs a case where a job is not desired to be shifted even if it has a room for shift. There is also a job which is not desired to be cut or relieved as described in the above (3). For example, a shop clean-up work should be cut rather than a register work which is more directly related to customer services.

In view of the above, a job scheduling system according to this invention is provided with

means for describing initial workload allocation, and knowledge and know-how for the workload allocation, in the form of rules.

According to the present invention, the provision of rule descriptive means enables to realize a system having a wide application field and easy to describe, add and modify various knowledge and know-how for the workload allocation and the like. Further, an improved optimum status and processing efficiency can be attained because of the inclusion of the fundamental workload balancing functions described in the above (3).

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a functional block diagram showing an embodiment of a job scheduling system with various tables according to the present invention;

Figure 2 is a schematic diagram illustrating a conventional system;

Figure 3 is an initial workload allocation rule table;

Figure 4 is a workload allocation rule table (for all resources);

Figure 5 is a workload allocation rule table (for each resource type);

Figure 6 is a capacity data table (for each resouce type);

Figure 7 is a capacity data table (for all resources);

Figure 8 is a flow chart showing a processing by the initial workload allocation part;

Figure 9 is a workload allocation result table (for each job);

Figure 10 is a workload allocation result table (for each resource type);

Figure 11 is a workload allocation result table (for all resources);

Figure 12 is a flow chart showing a processing by the workload allocation part;

Figure 13 is a flow chart showing a processing by the workload allocation part for all resources, which is a part of the flow chart of Fig. 12;

Figure 14 is a flow chart showing the detail of the start time delaying and hastening functions by the workload balancing means for all resources;

Figure 15 is a flow chart showing the detail of the job cutting function by the workload balancing means for all resource; and

Figure 16 is a flow chart showing the detail of the job relieving function which is the workload balancing means for each resource type.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a functional block diagram showing an embodiment of a job scheduling system with various tables according to the present invention. The relationship between each block and table will be detailed later, as it becomes necessary, with reference to other figures.

A main control part 101 sequentially actuates and controls a data input part 102, an initial workload allocation part 103, a workload balancing part 104 and an output part 105, to thereby obtain a resultant output.

The input part 102 stores input data regarding rules and resource capacities in each table 106 to 113. The description for the tables will now be given hereinafter.

Fig. 3 shows the structure of an initial workload allocation rule table 106. As a descriptive format for initial workload allocation rules, there is provided a basic statement of "as an initial workload for job [P_1], resource type [P_2] and number of persons [P_3] are allocated between [P_4] o'clock to [P_5] o'clock". P_1 to P_5 are given names and numerals for each job. The input part 102 stores the contents of a rule in the table 106 shown in Fig. 3, in accordance with the names and numeral values P_1 to P_5. Namely, the particular job name and resource type inputted as P_1 and P_2 are converted respectively into job number P_1' and resource type number P_2' by an editor in the computer for the purpose of simplicity of processing. The correspondence between them is decided when a rule is inputted. The inputted number of persons P_3 is stored directly in the table. The particular inputted times P_4 and P_5 are converted respectively into a start time unit number P_4' and an end time unit number P_5' by the editor in the computer. This correspondence between them is also decided when the rule is inputted. With this initial workload allocation rule, it is possible to allocate most suitable time units to the workload of a job.

Fig. 4 shows the structure of a workload balancing rule table (for all resources) 107. As a descriptive format for workload balancing rules for all resources, there is provided a basic statement of "IF (workload exceeds the resource capacity), THEN (apply workload balancing means [P_4] to job [P_1] between [P_2] o'clock and [P_3] o'clock, with priority [P_5])". The input part 102 stores the contents of a rule in the table 107 shown in Fig. 4, in accordance with the names and numeral values P_1 and P_5. One of the names, i.e., right-shift, left-shift and cut, of workload balancing means is designated. A priority order during application of a rule is designated as [P_5].

The names and times inputted as P_1 and P_3 are converted by the editor in the computer into corresponding numbers P_1' to P_3'.

Fig. 5 shows the structure of a workload balancing rule table (for each resource type) 108. As

basic statement of "IF (workload exceeds the resource type capacity), THEN (relieve job [P_2] by resource type [P_3], with priority [P_4])". The input part 102 stores the contents of a rule in the table 108 shown in Fig. 5, in accordance with the names and numerical values P_1 and P_4.

The names P_1 to P_3 are converted by the editor in the computer into corresponding numbers P_1' to P_3'.

Fig. 6 shows the structure of a capacity data table (for each resource type) 109. The table stores capacity data $\ell(i, j)$ for each resource type number (i) and each time unit number (j). Based on the data, it is evaluated if the workload for each resource type is in excess of the resource type capacity.

Fig. 7 shows the structure of a capacity data table (for all resources) 110. The table stores capacity data (for all resources) $\ell(j)$ for each time unit number

$$(j), \text{ wherein } \ell(j) = \sum_{j=1}^{I} \ell(i, j).$$

Next, the initial workload allocation part 103 will be described. By this part, an initial workload allocation is performed. The processing flow is shown in Fig. 8. First, at step 801 a workload of each job is allocated along the time axis (i.e., in a workload allocation result table (for each job) 111, and in a workload allocation result table (for each resource type) 112) as an initial workload, in accordance with the information in the initial workload allocation rule table 106. Particularly, the following processing is conducted for each job:

$$m(k, j) \leftarrow m(k, j) + P_3 \text{ for } k = P_1', j = P_4' \sim P_5'$$

$$n(i, j) \leftarrow n(i, j) + P_3 \text{ for } i = P_2', j = P_4' \sim P_5'$$

wherein m(k, j) denotes an item in the workload allocation result table (for each job) 111 shown in Fig. 9, which item represents a workload of a job number k at a time unit number j, and wherein n(i, j) denotes an item in the workload allocation result table (for each resource type) 112 shown in Fig. 10, which item represents a workload for a resource type number i at a time unit number j.

Next, at step 802 an initial workload of resources per each time unit j is calculated in accordance with the information in the workload allocation result table (for each resource type) 112 shown in Fig. 10, and the results are stored in a workload allocation result table (for all resources) shown in Fig. 11. The processing is performed by

$$n(j) = \sum_{j=1}^{I} n(i, j) \text{ for } j = 1 \text{ to } J,$$

wherein n(j) denotes an item in the workload allocation result table (for all resources) 113 shown in Fig. 11, which item represents a workload for all resources at a time unit number j.

Next, the workload balancing part 104 will be described. In this part, a workload balancing is performed to balance a workload within the resouce capacity if the workload is found in excess of the resource capacity at the initial workload allocation. It is necessary in this case that the workload for all resources be within the resource capacity. To this end, the basic workload allocation functions, i.e., start time delaying and hastening functions 114 and job cutting function 115 are first adopted. Thereafter, to make the workload of each resource type within the resource capacity, the job relieving function 116 is adopted. Fig. 12 is a flow chart illustrating such processing.

In the flow chart, first at step 1201 it is checked if the resource capacity is larger than the workloads of all resources and resource types. If the capacity is not larger than the workloads, the processing by the workload balancing part 104 stops. If the capacity is larger than the workloads, then the flow advances to the next step S1202. If the workload for all resources is not in excess of the capacity, step 1206 follows, whereas if affirmative at step 1202, step 1203 follows. At step 1203, it is checked if there is present any available workload balancing means for all resources (right-shift, left-shift or cut) in the workload balancing rule table (for all resources) 107 shown in Fig. 4. This judgement of availability if made in accordance with control flags in the table. The initial values of the control flags have been set such that all means are available. If there is no means which means that a workload balancing is not possible, the processing stops. If there is any available means, the flow advances to step 1204

whereat means having a highest priority among available workload balancing means (rules) for all resources is selected to conduct a workload balancing.

If the workload for all resources becomes within the resource capacity by virtue of the workload balancing at step 1205, the flow advances to the next step 1206. If the capacity is larger than the workloads of all resource types at step 1206, then the processing stops. If not, the flow advances to step 1207 whereas it is checked if there is any available workload balancing means (relieving means) for each resource type in the workload balancing rule table (for each resource type). If not, the processing stops. If affirmative, step 1208 follows to select means having a highest priority order among available workload balancing means to conduct a workload balancing which is performed by the job relieving function 116 shown in Fig. 1. If the workloads become smaller than the capacity for all resource types by the workload balancing at step 1209, the processing stops.

Next, the detail of step 1204 of Fig. 12 will be given with reference to Figs. 13 to 15.

As shown in Fig. 13, first at step 1301, means having a highest priority order among available means is derived by referring to the workload balancing rule table (for all resources) 107 shown in Fig. 4. The data P_1' to P_5 are substituted into q_1 to q_5. Using q_5 storing a name of the workload balancing means, it is checked at step 1302 and 1303 if it represents a right-shift or a left-shift. In case of a right-shift or a left-shift, a workload balancing is performed to complete such processing. If it is neither a right-shift nor a left-shift, a workload balancing through a cutting function is performed to complete such processing.

Next, the detail of step 1304 will be given with reference to Fig. 14.

First at step 1401, a time unit number j^* is derived whereat a job number q_1 to be right- or left-shifted has a workload in excess of a predetermined number of persons $(n(j)-\ell(j)>0)$. These data are collectively represented by a set $\{j^*\}$. Next, at step 1402, j^* of $\{j^*\}$ having a maximum $n(j^*)-\ell(j^*)$ is derived and represented by j^{**}. The reason for this derivation is that it is proper to balance a peak workload at first. Then at step 1403, it is checked if the workload balancing means is a right-shift. If affirmative, it is checked at step 1404 if J^{**} is smaller than q_3 (latest finish time unit number). If not smaller, it means that a right-shift is not available so that j^{**} is removed from $\{j^{**}\}$ at step 1405. If smaller, it is checked at step 1406 if there is a time unit number which can be subjected to a right-shift. In other words, it is checked if there is j which suffices $j^{**}<j\leqq q_3$ and $n(j)-\ell(j)<0$. If not, the flow returns to step 1405. If affirmative, j having a minimum (or minimum workload) $n(j)-\ell(j)$ is derived and represented, at step 1407, by j^{***} which is a destinatin or right-shift of j^{**}. To balance the workload one by one minutely, a workload in amount of one person of the job number q_1 at the time unit number j^{**} is shifted to the time number unit j^{***}. Particularly, the contents of the workload allocation result table (for each job) 111 shown in Fig. 9, the workload allocation result table (for each resource type) 112 shown in Fig. 10 and the workload allocation result table (for all resources) 113 shown in Fig. 13 are changed as in the following:

$$m(q_1, j^{**}) \leftarrow m(q_1, j^{**}) - 1$$

$$m(q_1, j^{***}) \leftarrow m(q_1, j^{***}) + 1$$

$$n(i^*, j^{**}) \leftarrow n(i^*, j^{**}) - 1$$

$$n(i^*, j^{***}) \leftarrow n(i^*, j^{***}) + 1$$

$$n(j^{**}) \leftarrow n(j^{**}) - 1$$

$$n(j^{***}) \leftarrow n(j^{***}) + 1$$

In the above, i^* is obtained, using q_1 as a key, from the initial workload allocation rule table.

After completion of step 1408, the flow returns to step 1409 to which step 1405 is also returned. It is checked at step 1409 if there is a time unit number j^* whose workload is shiftable. Namely, if the set $\{j^*\}$ is not an empty set (0), the above processes are repeated. If $\{j^*\}=0$, selected workload balancing means is caused not applicable. Particularly, the control flag of workload balancing means in the workload balancing rule table (for all resources) 107 shown in Fig. 4 is changed from 0 to 1 at step 1410.

In case of a left-shift instead of a right-shift as described so far, steps 1411 and 1412 corresponding to steps 1412 and 1406, respectively, are executed. The description therefore is omitted due to a similar operation to the latter steps.

The above description has been directed step 1304 of Fig. 12. Next, the detail of a workload

First at step 1501, a time unit number j^* is derived whereat a job number q_1 is in condition of $n(j)-\ell(j)>0$. These data are collectively represented by a set $\{j^*\}$. Next, at step 1502, it is checked if the set $\{j^*\}$ is an empty set (0). If $\{j^*\}$ is not equal to 0, j^* having a maximum $n(j^*)-\ell(j^*)$ is derived and represented by j^{**} at step 1503. A workload of the job number q_1 at time unit number j^{**} is cut by *a* persons. *a* is a minimum of $\{m(q_1, j^{**}), n(j^{**})-\ell(j^{**})\}$. The first term represents a workload which can be cut, whereas the second term represents an amount of excessive workload. Particularly, at step 1504 the contents of the workload allocation result tables are changed as in the following:

$$m(q_1, j^{**}) \leftarrow m(q_1, j^{**}) - a$$

$$n(i^*, j^{**}) \leftarrow n(i^*, j^{**}) - a$$

$$n(j^{**}) \leftarrow n(j^{**}) - a$$

In the above, i^* is obtained, using q_1 as a key, from the initial workload allocation rule table.

After completion of the cut operation for the time unit number j^{**}, the j^{**} is removed from the set $\{j^*\}$ at step 1505 to return to step 1502. If the set $\{j^*\}$ is not 0, the similar processes are repeated. If $\{j^*\}=0$, the flow advances to step 1506 whereat selected workload balancing, i.e., cutting means is caused not applicable. Particularly, the control flag of workload balancing means in the workload balancing rule table (for all resources) is changed from 0 to 1.

Next, the detail of step 1208 shown in Fig. 12 will be given with reference to Fig. 16. First at step 1601, the time unit number j is set at 1. The control flags of the workload balancing rule table (for each resource type) 108 are all initialized to be applicable at step 1602. Next at step 1603, a resource type number i^* is derived whose workload exceeds its capacity at a time unit number j (i.e., for i sufficing $n(i, j)-\ell(i, j)>0$). These data are collectively represented by a set $\{i^*\}$ which designate a resource type having an excessive workload and not subjected to a workload balancing. One of the resource types $\{i^*\}$ is selected and represented by i^{**} at step 1604. The resource type number i^{**} to be balanced is removed from the set $\{i^*\}$ at step 1605.

The resource type number i^{**} is then subjected to a workload balancing. First at step 1606, a rule with $P_1'-i^{**}$, control flag=0 (applicable) and a highest priority order is derived from the workload balancing rule table. The parameters P_2' to P_4 are substituted into q_2 to q_4, respectively. If a workload can be entered into a relief destination at step 1607 (i.e., $n(q_3, j)-\ell(q_3, j)<0$), and if there is a job number q_2 to be relieved at the time unit number j at step 1608 (i.e., $m(q_2, j)\neq 0$), then the relieving processing advances to step 1609. If one of the above two conditions is not met, the rule concerned cannot be used for the relieving operation so that the workload balancing rule is caused not applicable at step 1610. The flow returns to step 1606 to derive a next rule to be applied.

At step 1609 performing a workload balancing, a workload in amount of *b* persons of the resource type number i^{**} at a time unit number j is moved to a resource type number q_3, wherein

$$b = \min\{m(q_2, j), \ell(q_3, j) - n(q_3, j), n(i^{**}, j) - \ell(i^{**}, j)\}$$

Particularly, the workload allocation result table (for each workload type) 108 is changed as in the following:

$$n(i^{**}, j) \leftarrow \ell(i^{**}, j) - b$$

$$n(q_3, j) \leftarrow n(q_3, j) + b$$

If it is decided at step 1611 that the workload after the above relieving operation is not made within its capacity (i.e., if $n(i^{**}, j)-\ell(i^{**}, j)>0$), the flow returns to step 1610. If the workload of the resource type number i^{**} is made within its capacity, it is checked at step 1612 if there is another resouce type number not subjected to a workload balancing (i.e., $\{i^*\}=0$?). If $\{i^*\}$ is not 0, the flow returns to step 1604. If $\{i^*\}$ is 0, it is checked at step 1613 if the workload balancing has been completed for all the time unit numbers (i.e., i=j?). If not (i<J), j+1 is substituted to j at step 1614. If i=J, the processing stops.

After the above workload balancing procedure, the output part shown in Fig. 1 outputs the contents of the workload allocation result table (for each job) 111, the workload allocation

results table (for each resource type) 112 and the workload allocation result table (for all resources) 113. However, if the workload is decided not to be within the resource capacity, such a status is informed.

According to this embodiment, in contrast with the conventional system, the job can be allocated to any desired time at an initial workload allocation and in addition, left-shift, job cutting and relieving functions can be incorporated. Thus, a job scheduling having a variety of application fields can be realized. Further, a descriptive format of a rule with a definite statement is provided for expressing the know-how of the workload allocation and balancing, thus making it very easy to describe, add and modify the know-how. Furthermore, the system includes fundamental scheduling functions so that a suitable job scheduling can be realized in short time by merely changing the know-how.

According to the present invention, various conditions on the workload allocation and balancing can be taken into consideration. Thus, a suitable job scheduling can be realized for a variety of application fields to accordingly enable improved services and reduced man-power. Further, various conditions can be expressed in the form of rule so that the description, addition and modification of a rule are easy. Furthermore, the system includes fundamental scheduling functions so that even the conditions to be considered are changed, the system can readily cope with such change.

CLAIMS

1. A job scheduling method for scheduling of job allocation to various resources comprising the steps of:

inputting data associated with jobs and resources;

allocation a workload of each job to each time unit along a time axis in units of job;

allocating said workload to said each time unit in units of resource type;

calculating an initial workload for all resources at said each time unit, in accordance with said workload allocated in units of resource type;

performing a first workload balancing for a time unit whose initial workload for all resources exceeds a resource capacity, so as to make the workload at said time unit within said resource capacity;

after said first workload balancing, performing a second workload balancing so as to make the workload allocated in units of resource type within its resource capacity; and

outputting, as a job schedule, each workload at said each time unit obtained by said second workload balancing.

2. A job scheduling method according to claim 1, wherein said first workload balancing step includes a step of performing at least one of right-shift, left-shift and cutting processings for an excessive workload at said each time unit.

3. A job scheduling method according to claim 1, wherein said second workload balancing step includes a step of performing a relieving function for relieving a processing by one resource to another resource.

4. A job scheduling method for scheduling of job allocation to various resources comprising:

a first step of description initial workload allocation information for use in expression of job allocation to most suitable resource and time at an initial workload allocation;

a second step of describing workload know-how for use in workload balancing of a workload in excess of a resource capacity;

a third step of performing said initial workload allocation in accordance with said initial workload allocation information; and

a fourth step of performing said workload balancing by using a fundamental scheduling function designated by said workload balancing know-how.

5. A job scheduling method according to claim 4, wherein said fundamental scheduling function at said fourth step includes a step of delyaing and hastening a job start time, a step of cutting a job, and a step of relieving a resource to another resource.

6. A job scheduling method according to claim 4, wherein the descriptive format used in said initial workload allocation describing step and the descriptive format used in said workload balancing know-how describing step each have a definite statement.

7. A job scheduling system for scheduling of job allocation to various resources comprising:

means for describing initial workload allocation information for use in expression of job allocation to most suitable resource and time at an initial work-load allocation;

means for describing workload know-how for use in workload balancing of a workload in excess of a resource capacity;

means for performing said initial workload allocation in accordance with said initial workload allocation information; and

means for performing said workload balancing by using a fundamental scheduling function designated by said workload balancing know-how.

tion includes a function of delaying and hastening a job start time, a function of cutting à job, and a function of relieving a resource to another resource.

9. A job scheduling method according to claim 7, wherein the descriptive format used in said initial workload allocation describing step and the descriptive format used in said workload balancing know-how describing step each have a definite statement.

10. A job scheduling method substantially as hereinbefore described with reference to the accompanying drawings.

11. A job scheduling system constructed and arranged to operate substantially as hereinbefore described with reference to and as illustrated in Figs. 1 and 3 to 16 of the accompanying drawings.

Published 1988 at The Patent Office, State House, 66/71 High Holborn, London WC1R 4TP. Further copies may be obtained from The Patent Office, Sales Branch, St Mary Cray, Orpington, Kent BR5 3RD. Printed by Burgess & Son (Abingdon) Ltd. Con. 1/87.